**Realistic loss-of-coolant accident (LOCA) Evaluation Methodology
Applied to the Full Spectrum of Break Sizes
(FULL SPECTRUM^{TM} LOCA Methodology)**

**WCAP-16996-P/ WCAP-16996-NP Volumes I, II and III, Revision 0, "Realistic loss-
off-coolant accident [LOCA] Evaluation Methodology Applied to the Full Spectrum
of Break sizes (FULL SPECTRUM^{TM} LOCA Methodology)"**

REQUEST FOR ADDITIONAL INFORMATION (RAI)

FIRST SET OF RAI QUESTIONS

RAI Questions 1 through 19

Table 1: Summary of RAI Questions

Question No.	Subject	Date Issued	Date Responded	Disposition (O/C)[†]	Note
1	WCOBRA/TRAC MOD7A Revision 7				
2	TRAC-PF1/MOD2 Code				
3	Large-break LOCA (LBLOCA) and small-break LOCA (SBLOCA) phenomena identification and ranking tables (PIRTs)				
4	End of blowdown				
5	Gap conductance				
6	Pressurizer response				
7	Long-term cooling and PIRT				
8	SBLOCA boundary and Region-I to Region-II boundary				
9	Worst SBLOCA				
10	Loss-of-offsite power (LOOP) versus reactor coolant pumps (RCPs) operating)				
11	Loop seal behavior				
12	Worst break sampling				
13	Decay heat multiplier/sampling				
14	Number of SBLOCA cases sampled: 93 versus 124)				
15	SBLOCA upper limit break size				
16	Long-term cooling restriction				
17	Swelled or two-phase mixture level versus collapsed level				
18	High pressure safety injection (HPSI) curve basis and uncertainty				
19	SBLOCA axial power shape				

[†] O=Open; C=Closed.

Question 1: WCOBRA/TRAC MOD7A Revision 7

Code, scaling, applicability, and uncertainty (CSAU) methodology Step 4 emphasizes the identification and use of a frozen version of a mature code and Step 5 requires proper documentation consistent with the frozen code, which is used to determine the code maturity and applicability. Westinghouse's current methodology WCAP-16009-P-A, "Realistic Large-Break LOCA Evaluation Methodology Using the Automated Statistical Treatment of Uncertainty Method (ASTRUM)" (2005) is based on the frozen code version WCOBRA/TRAC MOD7A Revision 6. Applicant's previously approved best-estimate Large-break LOCA (LBLOCA) methodology was approved based on the frozen code version WCOBRA/TRAC MOD7A Revision 1. It is described in WCAP-12945-P-A "Code Qualification Document for Best Estimate LOCA Analysis" (1998) for Westinghouse designed 3- and 4-loop plants with emergency core cooling system (ECCS) injection into the cold legs and in WCAP-14449-P-A," Application of Best Estimate Large Break LOCA Methodology to Westinghouse pressurized water reactors (PWRs) with Upper Plenum Injection" (1999) for Westinghouse designed 2-loop plants with upper plenum injection. WCAP-16009-P-A Appendix B, "Validation of WCOBRA/TRAC MOD7A Revision 6," describes the differences between these two frozen versions and includes the evaluations performed to ensure that the prior code assessments against experimental data remained valid.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 1.2.7, "EMDAP Element 3 (Steps 10, 11 and 12): Develop Evaluation Model," states that the development of WCOBRA/TRAC-TF2 started from WCOBRA/TRAC MOD7A Revision 7. The section explains that this revision was released to reflect error corrections and minor improvements, including such related to additional features for special applications. It also clarifies that these changes were reported under the Section 50.46 of Title 10 of the *Code of Federal Regulations* (*CFR*) reporting requirements process. Please provide a list of the changes made in WCOBRA/TRAC MOD7A Revision 7 from the last approved version and identify those that are germane to WCOBRA/TRAC-TF2. In addition, describe the resolution of the changes in this category and provide specific references documenting their approval by the U.S. Nuclear Regulatory Commission (NRC).

Question 2: TRAC-PF1/MOD2

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 2.5, "WCOBRA/TRAC-TF2 Development Strategy," explains that the full spectrum LOCA (FSLOCA) code architecture was developed by inserting the WCOBRA/TRAC 3D Module based on COBRA-TF into the TRAC-PF1/MOD2 code while deactivating the 3D component in TRAC-PF1/MOD2. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 2.4, "Requirement Analysis/Assessment for WCOBRA/TRAC-TF2 Models," asserts that the 1D six-equation two fluid formulation of TRAC-PF1/MOD2 extended to the loops provides adequate formulation for both stratified flow simulation, required for SBLOCA, and limiting the mass error during slow draining transients in

comparison to the 1D five-equation drift-flux formulation of WCOBRA/TRAC (based on TRAC-PD2). Additionally, TRAC-PF1/MOD2 featured a non-condensable transport model.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 2.4 refers to "Open Literature, Theory Manual [1], and Assessment Report [2]" when discussing TRAC-PF1 expected capabilities (see WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Volume 1 page 2-44). Explain what "Open Literature, Theory Manual [1], and Assessment Report [2]" stand for in Section 2.4. Please identify the frozen code version of TRAC-PF1/MOD2 that was used in the development of WCOBRA/TRAC-TF2 and provide a complete set of references that document this code version. In addition, explain why this code version was considered to be mature for the purpose of WCOBRA/TRAC-TF2 development and describe the technical basis that was considered and evaluated in reaching this conclusion.

Question 3: LBLOCA and SBLOCA PIRTs

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 2.3, "Phenomena Identification and Ranking Table (EMDAP Steps 3 and 4)," explains that the FSLOCA PIRT was developed using "existing LBLOCA and SBLOCA PIRTs as the starting point." With regard to the previously existing LBLOCA PIRT, Section 2.3 stated that it was "the subject of NRC review." Please identify this existing LBLOCA PIRT, as approved by NRC, and provide a table that compares and documents all differences between the original approved LBLOCA PIRT and the FSLOCA PIRTs for LBLOCA and intermediate break LOCA (IBLOCA). In addition, explain the conversion process between the ranking system used in the existing LBLOCA (ranks from 1 to 9) and the system adopted in the new FSLOCA PIRTs ("Low," "Medium," and "High").

With regard to the previously existing SBLOCA PIRT, Section 2.3 clarifies that it was a subject of "independent peer review." Please identify this original SBLOCA PIRT along with its technical basis and supporting references describing its development. In addition, provide a brief summary of all major findings from the "independent peer review." Please present a table that compares and documents all differences between the original SBLOCA PIRT and the FSLOCA PIRT for SBLOCAs.

Question 4: End of Blowdown

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Subsection 2.3.1.2, "Large Break LOCA (LBLOCA) Periods Specification," explains that a large break LOCA transient can be characterized by three distinct periods: blowdown, refill, and reflood. It is further stated that the blowdown period extends from the initiation of the break until the primary side depressurizes to the point when "emergency core cooling (ECC) water can start to penetrate the downcomer." Subsection 27.2.1, "CGE Large Break Reference Transient Description," suggests that at the end of blowdown the primary

system pressure approaches the containment pressure, the break flow, and consequently the downward core flow are reduced, the core begins to heat up, and the vessel begins to fill with emergency core cooling system (ECCS) water. In this regard, the CSAU report (NUREG/CR-5249) describes the end of blowdown by the initiation of accumulator injection in the intact loops.

Please explain if there is any difference in these definitions with regard to the end of blowdown phase. As it remains unclear how the timing when ECC water "can start to penetrate the downcomer" is determined, please clarify if the time when the primary system pressure approaches the containment pressure (and when depressurization basically ceases) is appropriate to describe the end of blowdown. In addition, please explain what input the defined timing of end of blowdown has on ECCS performance and predicted peak cladding temperature (PCT).

Question 5: Gap Conductance

NUREG/CR-5249 CSAU Table 6, "Summary of Highest-Ranked Processes," listed the gap conductance as a separate process. Furthermore, CSAU Table 16, "Thermal Response of Fuel and Peak Cladding Temperature Change," illustrated that the effect of gap conductance on the blowdown PCT was the largest one. It was recognized that during blowdown the impact on the PCT from stored energy release to cladding prevails over that from decay heat generation. Accordingly, the gap conductance was considered in the uncertainty analysis. The CSAU PIRT, as presented in NUREG/CR-5249 Table 1, "Summary of Expert Rankings and AHP-calculated Results," rated this process low during the blowdown and refill periods and high during the reflood period as the CSAU report was probably documenting the process as it evolved. WCAP-16009 Table 1-1, "PIRT for Large-Break LOCA," while including the gas conductance, provides no ranking for this factor besides the CSAU ranking of 8 during blowdown.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Table 2-1, "PIRT for Full Spectrum LOCA for Westinghouse and Combustion Engineering Plants," does not include and rank fuel gap conductance. Studies show that gap resistance dominates at the beginning of irradiation (until closure) and becomes again important at increased burnup levels close to 70 GWd/tU due to significant gap conductivity decrease (see results by C.B. Lee, et al. as reproduced by M.T. Del Barrio, et al., "Analysis of FRAPCON-3 Models Related to High Burnup Fuel," 2006 International Meeting on Light Water Reactor Fuel Performance "Nuclear Fuel: Addressing the Future," October 22-26, 2006, Salamanca, Spain).

Please explain why WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Table 2-1, "PIRT for Full Spectrum LOCA for Westinghouse and Combustion Engineering Plants," does not include and rank fuel gap conductance and its impact on fuel stored energy and predicted PCT. Please also identify the codes and methods for

determining fuel gap conductance, fuel pin pressure, fuel temperatures, and stored energy versus burnup and explain their application and use in the FSLOCA methodology.

Question 6: Pressurizer Response

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Subsection 2.3.2.6, "Pressurizer/Surge Line," discusses processes related to the reactor pressurizer. Accordingly, WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Table 2-1, "PIRT for Full Spectrum LOCA for Westinghouse and Combustion Engineering Plants," provides the ranking for processes related to pressurizer level/liquid flashing. During blowdown, **[**

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Subsection 2.3.2.6, "Pressurizer/Surge Line," recognizes that the pressurizer level or pressure can initiate reactor trip. With regard to safety injection actuation, Subsection 2.3.1.3, "LBLOCA Periods Specification," explains that the ECCS is aligned for delivery following the generation of an "S" signal when the pressurizer low/low-pressure setpoint is reached with some delay. Although Subsection 2.3.2.6 states that reactor trip is not credited for large breaks, please explain if possible impact on the safety injection actuation was considered in the adopted ranking with regard to the pressurizer level swell/flashing for large and intermediate breaks.

When considering the pressurizer component, it is also recognized that the broken loop is not known in advance. Please explain why WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Subsection 2.3.2.6, "Pressurizer/Surge Line," provides no consideration with regard to possible effects associated with the break occurring in a loop connected to the pressurizer versus a break in a remaining loop without a pressurizer.

Question 7: Long-Term Cooling and PIRT

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Subsection 2.3.1, "LOCA Scenario Specification," identifies distinct periods that are used to characterize each LOCA sub-scenario. These periods are also used to identify and rank participating phenomena in the proposed PIRT. When discussing the 10 CFR 50.46(b) acceptance criteria for emergency core cooling systems for light-water nuclear power reactors in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 30.1, "Statistical Methodology Roadmap," the applicant states that the last two criteria, 10 CFR 50.46(b)(4) "Coolable geometry" and 10 CFR 50.46(b)(5) "Long-term cooling", are typically "satisfied outside the LOCA analysis once the LOCA calculation is demonstrated to be in compliance with the first three criteria." Section 32.3.1 "Regulatory Position 4, "Estimation of Overall Calculational Uncertainty"" further explains that Westinghouse methodology used to satisfy the long-term cooling criterion defined in

10 CFR 50.46(b)(5) is unaffected by the use of best-estimate techniques for the short-term transient calculation."

Phenomena germane to long-term cooling can have important impact on LOCA safety analyses. Thus, NUREG-0800, "Standard Review Plan," Section 15.6.5, "Loss-of-Coolant Accidents Resulting from Spectrum of Postulated Piping Breaks within the Reactor Coolant Pressure Boundary," requires analyses of both LBLOCAs and SBLOCAs performed to identify the timing for boric acid precipitation. Another phenomenon is re-plugging of the loop seals by SI water as recognized in Subsection 2.3.2.9 "Pump." The long-term cooling phase is not identified as a separate period in the general LOCA characterization provided in Subsection 2.3.1, "LOCA Scenario Specification." It is also not included as a separate LOCA in the FSLOCA PIRT provided in Table 2-1, "PIRT for Full Spectrum LOCA for Westinghouse and Combustion Engineering Plants." Please explain why such a period is not considered in the proposed FSLOCA PIRT and if the WCOBRA/TRAC-TF2 evaluation model is applicable for post-LOCA long-term cooling analysis.

In the context of long-term cooling, the NRC staff finds that use of WCOBRA/TRAC-TF2 should be limited only to demonstration that sufficient coolant (i.e. in excess of boil-off) is added to the core to maintain it covered with two-phase mixture and keep fuel temperatures acceptably low during the long term after core quench. Since the FSLOCA methodology does not treat boric acid precipitation, long-term cooling can not be completely addressed with this methodology. Therefore, the long-term cooling criterion defined in 10 *CFR* 50.46(b)(5) can not be stated as being satisfied by application of the FSLOCA methodology. Accordingly, this will be a limitation applied to this methodology.

Question 8: SBLOCA Boundary and Region-I to Region-II Boundary

The proposed Westinghouse FSLOCA methodology includes any break size causing a leakage beyond the capacity of the normal charging pumps up to and including a double ended guillotine rupture with a break flow area equal to two times the pipe area. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 2.3.1 "LOCA Scenario Specification," identifies three different LOCA sub-scenarios with regard to break area: small breaks, intermediate breaks, and large breaks. Subsection 2.3.1.3 "IBLOCA Periods Specification," clarifies that the IBLOCA break sizes, although somewhat plant dependent, generally range from 10-inch to 13.5-inch equivalent diameter (0.55 ft^2 to 1.0 ft^2). A proposed hybrid position for treatment of break type and size, described in Subsection 29.2.3 "Break Type, Split Break Area and Break Flow Model Uncertainty Methodology," divides the full spectrum of break sizes in two contiguous regions identified as Region-I and Region-II. **[**

] The subsection further explains that break sizes historically classified as intermediate breaks are included in both Region I and Region II. Thus, "Region-I provides coverage of what typically are

defined as SBLOCA scenarios and stretch into Intermediate Break LOCA (IBLOCA) whereas Region-II starts from Intermediate Break size and include what typically are defined LBLOCA scenarios" as stated in WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, "Executive Summary."

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 31.3, "Analysis of Results for Region I," presents a demonstration analysis of the FSLOCA methodology for a selected three-loop Westinghouse PWR. Subsection 31.1.1, "Break Area Ranges," employs a mechanistic model using WCT-TF2 to determine the minimum small break as **[**

] As discussed in Subsection 2.3.1.3, IBLOCAs generally range from 10-inch to 13.5-inch equivalent diameter (0.55 ft^2 to 1.0 ft^2 or 13.2 percent to 24.2 percent cold leg area). Please explain if there is inconsistency with regard to the intended coverage of the entire SBLOCA range in Region-I as proposed in the FSLOCA methodology.

To assess the adequacy of the proposed position for applying the uncertainty analysis to the full break spectrum and related treatment of the break size, the staff needs the following additional information. Please explain if an approach for determining an upper limiting break size for SBLOCAs, based on major controlling plant characteristics, has been considered for the FSLOCA methodology. The staff finds that the break size, selected to separate Region-I from Region-II, lacks relevant evidence to governing LOCA phenomena inherent to and defining the major LOCA categories. The staff finds it important that the upper break boundary for SBLOCA is based on phenomenological considerations that allow for the determination of such boundaries based on the scaling of major contributing parameters, such as reactor coolant system volume, power level, etc., on a plant specific basis. Accordingly, any division of the entire break spectrum into sub-regions in the uncertainty analysis should be based on similar considerations. Please address these items for the FSLOCA methodology.

Question 9: **Worst SBLOCA**

The WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 29.2.3 "Break Type, Split Break Area and Break Flow Model Uncertainty Methodology," proposes a position for the treatment of the break type and size **[**

] Section 29.2.3 claims that "this approach provides an adequate coverage of all possible LOCA scenarios" and Section 30.1, "Statistical Methodology Roadmap," asserts this is done **[**

]
According to Section 30.5, "Overview of Full Spectrum LOCA Statistical Procedure (ASTRUM-FS)," when generating a representative sample of the LOCA scenarios population, **[**

]
WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 31.3, "Analysis of Results for Region I," presents a demonstration analysis of the FSLOCA methodology for a selected three-loop Westinghouse PWR. For Region I, the break area is sampled between **[**

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To assess the appropriateness of the proposed position in the FSLOCA methodology regarding SBLOCA resolution and treating the worst break size in Region I, please present the results from an additional analysis for the demonstration three-loop Westinghouse plant (V. C. Summer (CGE)) examined in Section 31.3. In this analysis, please assume that the examined breaks range from 2.0-inch to 6.0-inch equivalent diameter (0.022 ft^2 to 0.196 ft^2 or 0.5 percent to 4.8 percent break area), **[**

] Please present the updated Figures 31.3-4 to 31.3-7 and Tables 31.3-1a and 31.3 1b to illustrate the obtained results. If this approach does not guarantee adequate resolution of the worst break, please consider an alternative method as discussed in the following paragraph. Please be aware that for some plants the PCT can increase by a few hundred degrees Fahrenheit when the break size changes from 0.05 ft^2 to 0.06 ft^2. Thus, it has been shown for some plants that the PCT can increase by approximately 100°F for a small break area increase of 0.005 ft^2 so that the 0.055 ft^2 break PCT is higher than both the 0.05 ft^2 and 0.06 ft^2 break. This limiting break is characterized by RCS pressure that just depressurizes to a pressure within several psi of the safety injection tank (SIT) actuation pressure. Because such behavior characterizes most plants, it is necessary to resolve the size of the worst break

controlled entirely by the HPSI injection only. While this low range of small break sizes is most pronounce under Appendix K analysis assumptions, it still needs to be evaluated in the best estimate space since future increased power levels and linear heat generation limits will also produce such a temperature spike for such a small break window. The included figure illustrates the described PCT behavior. In addition, sometimes this worst break size can be just slightly larger than that at which SIT injection is prevented. In this case, a small amount of injection after a deeper core uncovery can often lead to the worst break because SIT injection quickly terminates with only a small increase in core level as the RCS pressure can quickly increase with the small level change.

To assess the appropriateness of the proposed position in the FSLOCA methodology regarding SBLOCA resolution and treating the worst break size in Region I, please present the results from an additional analysis for the three-loop Westinghouse plant examined in Section 31.3. In this analysis, please assume that Region I breaks range from 2.0-inch to 6.0-inch equivalent diameter (0.022 ft^2 to 0.196 ft^2 or 0.5 percent to 4.8 percent break area) and vary the break in increments of 0.2 inch. Please perform the analysis assuming nominal values for all remaining sampled parameters including the break discharge coefficients. In addition, show the effect of key parameter variations from the nominal values over this detailed range and present the updated Figures 31.3-4 to 31.3-7 and Tables 31.3-1a and 31.3-1b using the obtained results.

In both approaches the Region I **[**

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Please also show the spectrum evaluation for the Beaver Valley Unit 1 three-loop PWR plant considered in WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 26.3, "Beaver Valley Unit 1 Nuclear Power Plant," and compare the break spectrum results with the Appendix K more limiting analysis.
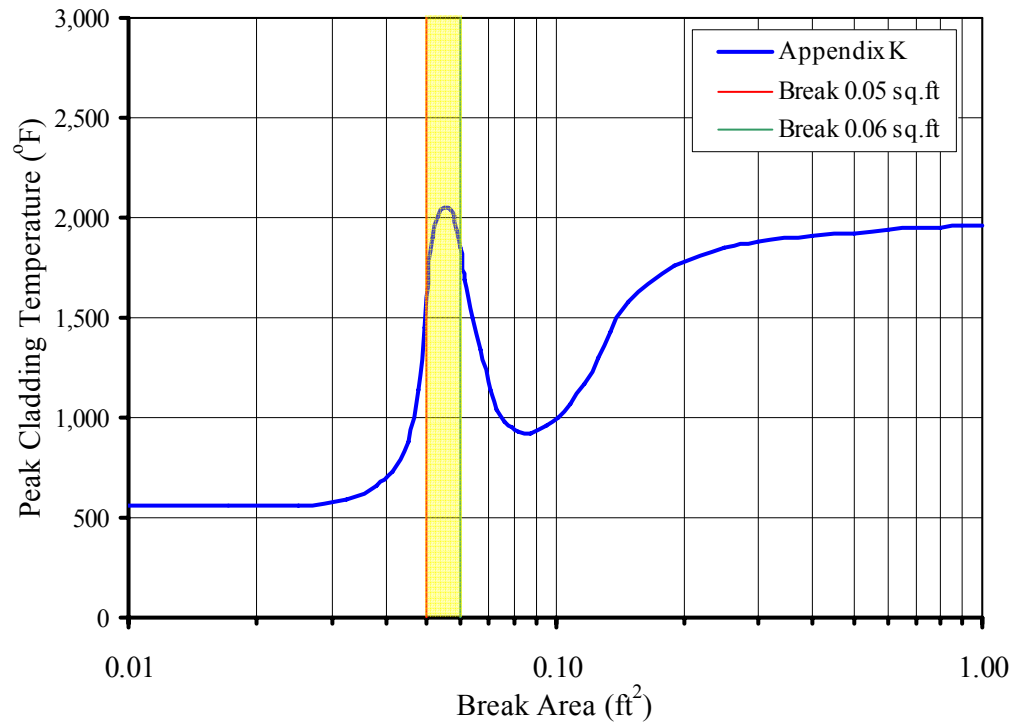
Figure: Illustration of PCT Response to Break Size Variation for Appendix K SBLOCA Analysis

Question 10: **LOOP versus RCPs Operating**

If LOOP is assumed at break time, please justify that this assumption is appropriate since LOOP at time of pressurizer low/low-pressure trip setpoint produces a more severe result for SBLOCA. Furthermore, if there is no LOOP during SBLOCA, what is the limiting break size and location with PCT identified, using the FSLOCA methodology? How is the emergency operating procedure trip timing modeled including operator error and uncertainty when simulating SBLOCAs with RCPs running. Please explain and show the break spectrum with RCPs running. Furthermore, it is not clear that cold leg breaks are always the limiting location as stated in Section 2.3.1, "LOCA Scenario Specification," given the effects of operating RCPs during the event. With RCPs operating, the limiting break may be a hot leg break. Please also describe any changes to the models for key SBLOCA phenomena that are impacted if RCPs are operating for SBLOCAs. In addition, please explain why the PIRT did not specifically include SBLOCA phenomena with the RCPs running. In this regard, it is explained in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 2.3.1, "LOCA Scenario Specification," that "the availability of the RCPs following reactor trip is considered, so variability in the pump trip time does exist."

Question 11: Loop Seal Behavior

Loop seal clearing is a major physical phenomenon that controls PCT for small break LOCAs. Integral test data shows that for break sizes lass than 5-inch equivalent diameter in the discharge cold leg, only one loop seal clears. And for example, for Semiscale Test S-O7-10D, there is also residual water remaining in the horizontal section of the suction legs that clear. Furthermore, loop seal clearance following small breaks is very difficult to predict with T/H codes and as such, modeling break sizes less than 5-inch diameter should only credit the clearing of one loop seal. Table 31.3-1b shows the limiting PCT to be 906 $^{\circ}$F for Case 059. Case 059 predicted three loop seals clearing. Test data shows that break sizes less than 5-inch diameter do not exhibit more than one loop seal clearing. Please repeat the analysis for Case 059 with only one loop seal cleared. Also, if residual water remains in the horizontal section, how is the vapor flow area in this region modeled and computed? Please explain. In addition, please describe if the hot leg nozzle gaps and core barrel leak paths are credited. Please repeat 059 with the nozzle gaps and core barrel leakage paths closed. What is the impact of these assumptions on the Beaver Valley Region I break spectrum, particularly the limiting small break as identified in Question 9?

Question 12: Worst Break Sampling

The small break spectrum for many PWRs will show the limiting small break to be in the range from 0.05 ft^2 to 0.2 ft^2 in the cold leg (3.03 inch to 6.06 inch). Depending on the axial power distribution, SIT pressure, core power (decay heat), and HPSI injection flow capacity, PCTs can increase significantly within a small window of break sizes of plus or

minus 0.01 ft^2 to 0.005 ft^2. In this break range, the worst break size is the largest small break that does not actuate SITs as the RCS depressurizes to values just slightly above the SIT actuation pressure (within a couple psi). Sampling the break spectrum in Region-I as it is described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, Section 29.2.3, "Break Type, Split Break Area and Break Flow Model Uncertainty Methodology," will not adequate resolve this detail or identify this worst break. Break sizes of plus or minus 0.005 ft^2 in the above range about this break size, which is often thought to be limiting but identified with too coarse a spectrum of analyzed breaks, can show an increase of 100°F - 200°F when the worst break is found. The concern is that the proposed approach for Region I is not adequate in identifying this limiting break. **[   ]** Either much more sampling is required or this break should be first found deterministically assuming nominal initial conditions and then statistics is applied appropriately for a spectrum of sizes about this peak to assure the limiting break is found. Since power level is a key ingredient driving the PCT, use of the current power levels may not show this distinct peak or narrow spike behavior. As such, please find this break size for the Beaver Valley demonstration plant and increase the thermal power by 15 percent - 20 percent to show future expected behavior for possible power uprates using the FSLOCA methodology. This analysis should allow only one loop seal to clear if the break size is less than 5 inches. For this analysis, please use a decay heat multiplier with an upper 2-σ multiplier. For the purpose of finding this limiting break size, the limiting conditions for PLHGR, core power (decay heat nominal plus 2-σ), limiting top skewed shape, minimum HPSI head flow curve, one loop seal cleared, no hot leg nozzle gap and core barrel leakage paths open, and closed upper head venting should be assumed. This question is closely related to Question 9.

Question 13: Decay Heat Multiplier/Sampling

It is not clear how the decay heat multiplier is computed. Please provide a detailed explanation of the methods used to compute the nominal decay heat curve and then show how the uncertainty is computed as a multiplier (multiplication factor) applied to the total decay heat. Choosing an initial multiplier and applying it throughout the entire transient is not considered realistic or justified. Decay heat multipliers less than 1.0 are not considered acceptable. There are many decay chains comprising the total decay heat and as such, the applied decay heat multiplier during the transient should be sampled between 1.0 and the upper 2-σ level. σ may change with time but this must be justified. Furthermore, use of the 1979 American Nuclear Society (ANS) decay heat standard (as well as all other standards) may not be appropriate for best-estimate determinations because the data from the standard was not developed for best-estimate determinations other than Appendix K 'type " assessments and analysis. Lastly, it is not clear how one determines the nominal curve using the ANS standards. In view of these concerns, please describe an approach that accounts for all known uncertainties in arriving at a decay heat curve that represents the nominal plus the upper 2-σ interval.

Question 14: Number of SBLOCA Cases Sampled: [   ]

What is the basis for the **[   ]** chosen for the SBLOCA Region-I sample size described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 30.3.1, "Tolerance Intervals and Sample Size?" Given the PCT and oxidation criteria, at least 124 cases are necessary to properly capture the limiting break with the 95/95 probability statement. However, given the concerns with regard to resolving the worst break as discussed above in Question 11, please either propose a strategy that incorporates a deterministic identification of the worst break or propose additional sampling cases that will always capture this worst break size. If a sampling approach is chosen, it should be shown to identify the same limiting break size as that for the deterministic approach.

Question 15: SBLOCA Upper Limit Break Size

The upper limit to the break size in Region-I **[**
          ] The small break spectrum should include break sizes up to approximately 1.0 ft^2. This upper limiting small break needs to be identified and justified. A small break spectrum that ends at **[   ]** is missing the remaining portion of the small break spectrum. As such, use of the selected **[   ]** break as an upper limit is inappropriate. Furthermore, the upper limit should be scaled based on power and plant physical characteristics such as volume. For example, a 0.15 ft^2 break for a high power and large RCS volume plant will produce the same result as that for a smaller break size for a plant with a lower power and a smaller RCS volume with all other inputs being scaled correspondingly. Please identify and justify the small break spectrum and show how the small break spectrum upper limit changes with proper scaling of key plant parameters (power and volume).

Question 16: Long-Term Cooling Restriction

The staff does not agree that the WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, FSLOCA methodology completely satisfies the long-term cooling requirement even if it addresses 50.46(b)(1) through 50.46(b)(5) criteria. To satisfy criterion 50.46(b)(5), the prevention of boric acid precipitation should be addressed and shown to be prevented for all break sizes. This is currently done using Appendix K models and analyses. Boric acid precipitation was not addressed in the WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, FSLOCA methodology. Therefore, the staff will restrict the use of the FSLOCA methodology to only addressing criteria 1 through 4. The FSLOCA methodology should, of course, demonstrate that, once the core temperature have been reduced to acceptably low temperatures, the FSLOCA thermal hydraulic analysis predicts that the injection exceeds boil-off after core quench and therefore the core remains covered with two-phase mixture. It must also be demonstrated that the loop seals do not refill with liquid and depress the level into the

core during the long term. The WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, FSLOCA methodology document in Section 2.3.2.9, "Pump," and in Section 31.3, "Analysis of Results For Region I," explains that **[**
> **]** Show this behavior and demonstrate that during the long-term cooling phase heat up does not cause reheating of the fuel cladding.

Question 17: Swelled or Two-Phase Mixture Level versus Collapsed Level

WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, mentions the collapsed liquid level in many assessments and analyses. It is important to emphasize that the key parameter determining core uncovery and heat up is the two-phase mixture level. That is, the same liquid level could have different mixture levels and rates of attendant heat up. Therefore, all calculations should show the two-phase mixture level versus time as the key figure of merit for small breaks and not the liquid level. Please describe how this mixture level is determined for all small breaks. Describe the treatment of steam cooling heat transfer and heat up in the cell containing the two-phase mixture surface. How is the vapor superheat computed when the two-phase mixture surface is very near the bottom of the cell? Do all cells containing saturated liquid, regardless of whether the cell contains the two-phase mixture surface, treat the vapor as saturated also? Since T/H codes can artificially entrain liquid from the surface and expel drops into the upper vapor region of the core, please explain and demonstrate that liquid drops are not artificially expelled into the vapor region during long-term uncovery of the core for small breaks. Please explain what is done in the code to prevent such behavior in the WCOBRA/TRAC-TF2 vessel model.

Question 18: HPSI Curve Basis and Uncertainty

Please explain how the HPSI curve is generated for SBLOCA analyses and show that the uncertainty in pressure and flow is accounted for based on the HPSI surveillance measurements. Show a representative HPSI curve used in the FSLOCA SBLOCA evaluation and explain how it relates to the surveillance head and flow measurement considering and including all uncertainties.

Question 19: SBLOCA Axial Power Shape

Please provide the axial power shapes in the FSLOCA SBLOCA evaluations and explain how they are generated and sampled in the evaluation. In addition, please show the limiting axial power shape for the limiting SBLOCA size.